Toxic Contaminants

Summary

Toxic contaminants are present throughout the Puget Sound environment, though serious problems occur in urban areas near contaminant sources. Limited trend information suggests that some aspects of toxic contamination are decreasing (e.g., concentrations of metals in the waters of Commencement Bay) while other problems may be worsening (e.g., an increasing trend in the occurrence of liver lesions in English sole from Elliott Bay). Studies in some Puget Sound locations show toxic effects in invertebrates and fish. Levels of contamination in harbor seals may be high enough to cause adverse effects to these animals.

Toxic Contamination Concerns in Puget Sound

Human activities introduce toxic contaminants, including organic compounds and metals, to the Puget Sound environment. Some toxic substances, notably metals and hydrocarbons, occur naturally but become concentrated in the environment through human activities. Some of the sources of toxic contaminant input to Puget Sound include: stormwater runoff from urban areas; discharges of municipal and industrial wastewater; spills from vessels and shoreline and upland properties; pesticide runoff from agricultural, residential and park lands; aquacultural applications of pesticides; leaching of contaminants from shoreline structures (e.g., preservatives from pilings) and vessels (e.g., antifouling agents); channel dredging and dredged material disposal; and atmospheric deposition of air pollutants.

Humans have synthesized a variety of compounds that have been released to the environment. Some of these compounds have been specifically designed to be toxic

Oil spills in Puget Sound

Oil spills release toxic contaminants to the Puget Sound environment. Four spills released 10,000 or more gallons of petroleum or petroleum products to the waters and land of the Puget Sound basin between 1992 and 1999. A June 1999 spill from the Olympic pipeline in Bellingham was the basin's largest spill since 1991. In the Puget Sound basin, 120 oil spills of 25 to 10,000 gallons were reported to the Department of Ecology from July 1992 to June 1999.

(e.g., pesticides such as DDT and anti-fouling agents such as tributyltin). These compounds are often purposefully applied to the environment; they can also enter the environment through spills or improper disposal.

A variety of other compounds are designed and used for other purposes but happen to be toxic due to their chemical structure (e.g., polychlorinated biphenyls, or PCBs, used in a variety of industrial applications; and phthalates, used as plasticizers). These compounds typically enter the environment through incidental or accidental releases during their use or disposal.

A final group of toxic organic compounds are not purposefully generated but are toxic byproducts of society's activities (e.g., chlorinated dioxins and furans formed during some pulp bleaching processes; and polycyclic aromatic hydrocarbons, or PAHs, formed during the combustion of fossil fuels). These compounds often form in wastewater and combustion gases, which are released to the environment as part of discharges permitted by regulatory authorities. They can also be released to the environment through improper waste management and unpermitted discharges.

Human-made and naturally occurring chemicals can affect biological resources and humans in a number of ways. Concern over many chemicals relates to their ability to cause or promote the development of cancer in humans and other animals. Chemicals that are known or suspected causes of cancer include dioxins, PCBs, chlorinated organic pesticides and some PAHs. Organic compounds and metals can also cause ill effects to specific biological systems. For example, lead and mercury can cause neurological problems in humans, especially during fetal and childhood development, and in other animals as well. In recent years, scientists have found that some environmental contaminants interfere with normal hormone functioning and can cause reproductive problems. For example, a variety of organic compounds, including dioxins, PCBs and phthalates, have been shown to have estrogen-like activity. In addition, scientists have begun to show that environmental contamination (e.g., by PCBs) can cause immune function problems that can increase one's susceptibility to disease.

Many toxic contaminants cause additional problems because they accumulate in the tissues of organisms. Concentrations of some toxic chemicals become magnified through the food web when predators eat contaminated prey. This means that high-level predators can be exposed to much higher concentrations of contaminants than organisms that feed lower in the food web.

Toxic contaminant issues in Puget Sound are managed through a variety of programs. Ongoing release of toxic contaminants to the environment is addressed by controls on the discharge of wastewater from municipal and industrial facilities and by the implementation of best management practices for the management of stormwater and the prevention and clean up of spills. Toxic contaminants present in Puget Sound's sediments are addressed by sediment clean-up actions (page 50) and the management of dredged materials. In some cases, contamination can occur from atmospheric transport of pollutants both locally and globally (from nations where sources are not well regulated).

Findings

Toxic contaminants are pervasive throughout the Puget Sound ecosystem and there are many possible approaches to monitoring and reporting on the status and trends in Puget Sound's toxic contamination. This chapter presents information from PSAMP and other studies of toxic contaminants in Puget Sound, moving from sediment and

Table 5. Puget Sound waters identified as impaired by toxic contaminants

Water Resource Inventory Area (WRIA) – Basin Name	Waters Listed as Impaired by Toxic Contaminants	
	Marine Waters (reason for listing)	Fresh Waters (reason for listing)
1 – Nooksack	Bellingham Bay; Strait of Georgia (various)	
3 – Lower Skagit	Padilla & Fidalgo bays & Guemes Channel (PCBs)	
5 – Stillaguamish		Stillaguamish River (arsenic, copper, lead, nickel)
7 – Snohomish	Port Gardner & Inner Everett Harbor (various); Ebey Slough (bioassay)	Skykomish River (copper, lead, silver); Snohomish River (PAHs)
8 – Cedar/Sammamish		Lake Union & Ship Canal (dieldrin, bioassay); Lake Washington (bioassay); multiple areas of May Creek (lead, zinc); Kelsey Creek (DDT, dieldrin, heptaclor epoxide); Bear-Evans Creek (mercury)
9 – Green/Duwamish	Elliott Bay; Duwamish Waterway (various)	Springbook (Mill) Creek (various metals, bioassay)
10 – White/Puyallup	Inner & Outer Commencement Bay (various); Thea Foss Waterway (dieldrin, PCBs)	White River (mercury, copper); Wilkenson Creek (copper); Puyallup River (arsenic)
12 – Chambers Creek		Lake Steilacoom (sediment bioassay); Chambers Creek (copper, PCBs)
13 – Deschutes	Inner Budd Inlet (various)	Ward Lake (PCBs)
15 – Kitsap	Dyes Inlet & Port Washington Narrows; Eagle Harbor; Port Gamble Bay; Sinclair Inlet; Port Orchard, Agate and Rich passages; Quartermaster Harbor (various)	
18 – Dungeness/Elwha		Elwha River (PCBs)

Source: Department of Ecology.

the water column through the food web to invertebrates, fish, birds and mammals. The various ecosystem components provide a robust set of information about the status of contamination in Puget Sound, its geographic distribution and evidence of trends over time.

Based on evidence available through 1998 from sediments, surface waters and biological resources, Department of Ecology staff labeled 42 fresh and marine waters in the Puget Sound basin as "water-quality limited" because of toxic contaminants. Table 5 identifies these 23 marine water and 19 fresh water areas.

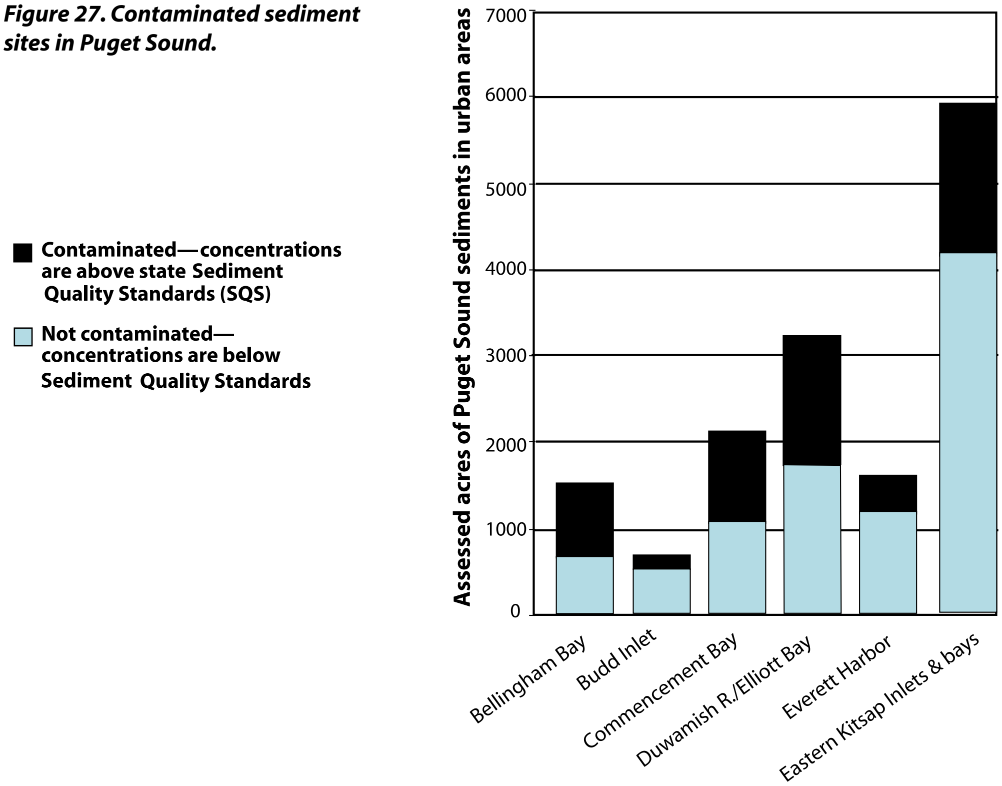
Sediment Contamination

Sediments are widely considered to be the major repository for toxic contaminants of concern in Puget Sound. They are also the primary source of contaminants in biota. The PSAMP therefore emphasizes sediment monitoring as a critical element in its characterization of toxic contamination in Puget Sound.

The 303(d) list and impaired waters

A discussion of the 303d list and how it identifies polluted estuaries, lakes and streams in Washington state appears in the Physical Environment chapter of this document on page 17.

Figure 27. Contaminated sediment sites in Puget Sound.



Source: Department of Ecology.

As of 1999, Department of Ecology staff had compiled sufficient data in their sediment quality database (SEDQUAL) to characterize more than 15,000 acres of Puget Sound's urban embayments (Department of Ecology, unpublished data). Thirty-eight percent of this area, 5,750 acres, was identified as contaminated above the state's sediment quality standards (Figure 27). Eighty-six of the most highly contaminated, discrete areas (estimated at 3,200 acres) within these urban embayments were identified as contaminated sediment sites, requiring cleanup directed by either state or federal cleanup laws. These sites are currently in various stages of cleanup: 15 have been cleaned up since 1996 and the remaining sites are being investigated to support the planning and design of cleanup activities.

Ecology staff used data newly available in January 1996 to characterize almost 1,400 acres of Puget Sound sediment (of the 15,000 acre total) that were not previously evaluated. Nearly 48 percent of this area, 660 acres, was identified as contaminated above state sediment quality standards. The high rate at which contaminated areas continue to be identified indicates that evaluations of urban bays remain incomplete. Consequently, larger areas of Puget Sound's urban embayments may be identified as contaminated when additional data become available.

Ecology's 1997 Evaluation of Sediment Contamination in North Puget Sound. In 1997 Ecology scientists altered the design of their study of marine sediment contamination to take advantage of an opportunity to partner with the National Oceanic and Atmospheric Administration's (NOAA's) National Status and Trends Program and to improve their characterization of the more contaminated areas of Puget Sound (the original design primarily targeted areas of Puget Sound with little contamination).

The overall goal of the 1997 Ecology-NOAA project was to estimate the percentage of north Puget Sound in which sediment quality is significantly degraded. This study used a stratified-random sampling approach, allowing the data to be extrapolated from sampling stations to a larger, defined surrounding area (i.e., a stratum). These data could then be used to estimate the spatial extent of chemical contamination and toxicity within a specified geographic area with a quantifiable degree of confidence (Long et al., 1999).

One hundred samples were collected during June and July 1997 at locations selected randomly within 33 geographic strata. The strata covered the area from Port Gardner, near Everett, to the U.S./Canadian border. Strata were selected to represent

Sediment contaminant monitoring in Puget Sound – a collaboration between the Department of Ecology and NOAA

In 1997, the goals and schedules of NOAA's National Status and Trends Program and Ecology's PSAMP sediment component aligned well and a three-year collaborative project was developed. Through this joint effort, approximately one-third of the area of Puget Sound was characterized each year from 1997 to 1999. The collaborating scientists have completed a report on the 1997 effort to characterize north Puget Sound (Long et al., 1999). The accompanying paragraphs summarize the results presented in the Ecology-NOAA report. The 1998 and 1999 results for central and south Puget Sound, respectively, are presently being analyzed. Reports on these areas are expected later in 2000 and in 2001.

Figure 28. Sampling stations in north Puget Sound with trace metal concentrations exceeding Washington state criteria.

Metals occur at concentrations above state Sediment Quality Standards (SQS).

Metals occur at concentrations above the state Cleanup Screening Level (CSL)

PCBs occur at concentrations above state's SQS and NOAA's Effects-Range Median screening values

conditions near Everett, Anacortes, Bellingham and Blaine, and the marine environments between these cities. Sediments from each of the 100 locations were analyzed for toxic contaminants and physical sediment characteristics, subjected to four toxicity tests and characterized by the organisms dwelling within them.

The highest chemical concentrations in north Puget Sound were seen in sediments from the two most urbanized embayments, Everett Harbor and Bellingham Bay. The pattern was most evident for several metals and PAHs. PAH concentrations were also relatively high in sediments near Anacortes (and nearby March Point), another urbanized area with significant petroleum refining and transport facilities. In contrast to these patterns, a sample from southern Boundary Bay, far from obvious sources of contamination, had a very high mercury concentration.

Results of chemical analyses indicated that relatively wide ranges in concentrations of some contaminants occurred among the 100 samples. However, only a small proportion of the samples had elevated concentrations of most contaminants.

- In samples from five stations, at least one metal occurred at a concentration at or above the state's sediment quality standards (SQS). Four of these stations were from inner Bellingham Bay and Everett Harbor, both urbanized bays, and one station was in Boundary Bay. Based on the program's random sampling design, these stations (Figure 28) represented about 3,200 acres (13 square km), equivalent to approximately 1.7 percent of the north Puget Sound study area.
- PAH concentrations did not exceed the state's SQS, but samples from eight stations in Everett Harbor had levels above NOAA's Effects Range Median (ERM) screening value for the sum of seven low molecular weight PAH compounds (Figure 29, page 52). One of these stations also had a total concentration for six high molecular weight PAH compounds above NOAA's ERM screening value.
- A sample from one location in inner Everett Harbor had total PCB concentrations above the state's SQS and NOAA's ERM screening value (Figure 28). This station represents less than 0.1 percent of the north Puget Sound study area.

Toxicity tests indicated that less than five percent of the north Puget Sound survey area was highly toxic. North Puget Sound sediments are among the least toxic that NOAA has evaluated in its surveys of the nation's estuaries. An amphipod survival test failed to identify any highly toxic samples, but three other tests indicated that samples

Measuring sediment quality

Chemical contaminants measured in sediments collected from Puget Sound are compared with critical values that have been set and adopted into law by the state of Washington. They are also compared with critical values that have been generated by federal researchers at NOAA based on sediment monitoring work conducted in more than 30 estuaries nationwide.

The "Washington State Sediment Management Standards" include two tiers of criteria against which sediment quality data are evaluated: (1) Sediment Quality Standards (SQS)—sediment concentrations above which adverse biological effects are expected and (2) Cleanup Screening Levels (CSL)—sediment contaminant concentrations higher than SQS above which active cleanup is required.

NOAA standards developed by Long et al. (1995) also include two tiers of criteria against which sediment quality data are evaluated: (1) Effects Range Low (ERL)—sediment concentrations below which toxic effects are not expected and (2) Effects Range Median (ERM)—sediment contaminant concentrations above which higher probabilities of toxic effects would occur.

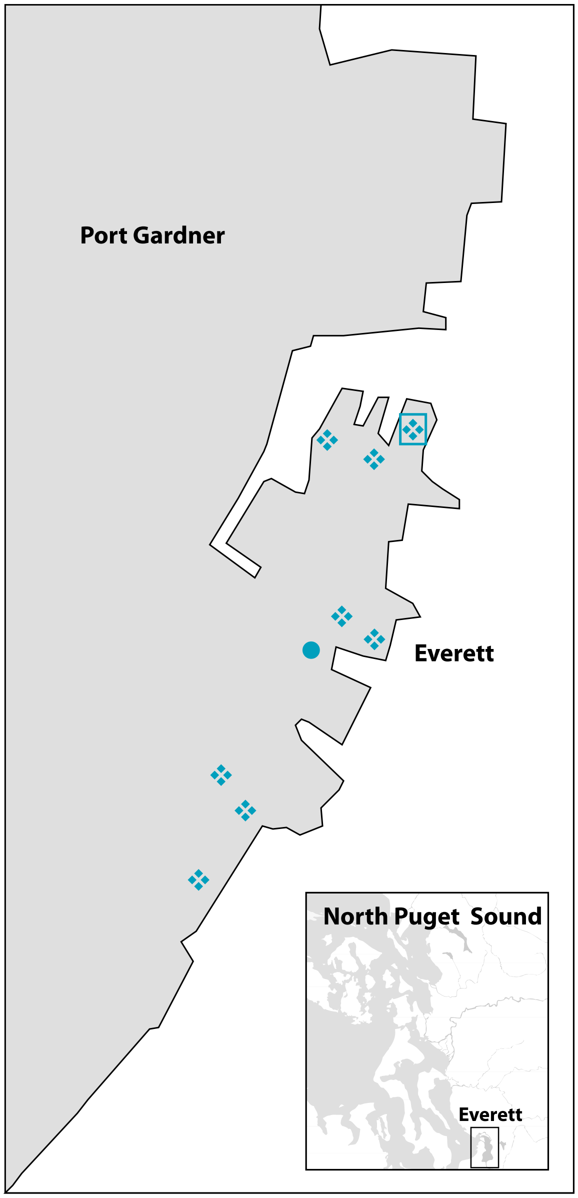
Figure 29. Sampling stations in Everett Harbor with concentrations of PAHs above screening guidelines.

Total concentration of seven low molecular weight PAHs exceed NOAA's Effects Range Median guidelines

Total concentration of six high molecular weight PAHs exceed NOAA's Effects Range Median guidelines

Sum of PAHs below NOAA's guidelines

No stations in the remainder of the north Puget Sound study area had PAH concentrations above these guidelines.



Evidence of toxic contaminant-induced degradation in north Puget Sound

Among the 100 stations evaluated by Ecology-NOAA in 1997, 18 stations had at least one chemical concentration above a guideline value, at least one toxicity test that indicated highly toxic conditions, and some degree of reduced diversity and abundance of the sediment-dwelling community. These stations were located in Everett Harbor, Port Gardner, Drayton Harbor, Bellingham Bay, Padilla Bay and Fidalgo Bay. Only the Everett Harbor stations, and possibly Port Gardner, had sediment-dwelling communities that suggested "strong evidence of pollution-induced degradation."

from Everett Harbor were the most toxic in the study area. Two tests (Cytochrome P450 RGS and Microtox™) demonstrated a gradient of increasing toxicity from the entrance to the head of Everett Harbor. Less severe toxicity was observed in the remainder of the study area. Other locations that showed toxicity included Drayton Harbor, Whatcom Waterway and other portions of Bellingham Bay, inner Padilla Bay, March Point, Fidalgo Bay, Port Susan and parts of Port Gardner. Sediments from Saratoga Passage, Possession Sound and most of Port Gardner were among the least toxic in these tests.

Ecology scientists intend that the results of the 1997 collaboration with NOAA will provide the basis for quantifying changes in sediment quality in north Puget Sound in future years. By repeating sediment quality measurements in future years using a study design comparable to the 1997 study, they can measure improvement or degradation in sediment quality. Data from north Puget Sound will be combined with those from central Puget Sound (sampled in 1998) and south Puget Sound (sampled in 1999) to assess the quality of sediments across the entire Puget Sound basin.

Streambed Sediment Contamination in the Puget Sound Basin. Concentrations of many metals, including arsenic, cadmium, chromium, lead, mercury, nickel and zinc, have been detected at higher concentrations in Puget Sound basin streambed sediments from agricultural and urban sites than in sediments from forest and reference sites (MacCoy and Black, 1998). A 1995 study by the U.S. Geological Survey (USGS) evaluated concentrations of toxic contaminants in streambed sediment and aquatic organisms and their relation to land use. The study detected pesticides in streambed sediments at three of 18 sampling locations in the Puget Sound basin. The highest pesticide concentrations were measured at the urban site. PAHs were detected frequently in streambed sediment samples from urban streams. USGS scientists concluded that developed land uses may have led to increased levels of contaminants, though the generally low levels observed do not necessarily suggest negative impacts in the environment (MacCoy and Black, 1998).

Toxic Contaminants in Water

Due to the rapid dilution in the surface waters of Puget Sound, the PSAMP does not emphasize analysis of water samples for toxic contaminants. Many toxic contaminants accumulate in sediments or in biological tissues, making toxic chemicals easier to measure in these other media than in water.

Metals in Rivers and Streams. The waters of Puget Sound's rivers and streams appear to be free of appreciable contamination from metals. Six times per year, Ecology scientists analyze water samples from selected Puget Sound rivers for metals. Samples collected since late 1996 have not contained metals at concentrations above the applicable water quality standards.

Pesticides in Urban Streams. A variety of frequently purchased pesticides are present at levels of concern in urban streams in the Puget Sound basin. The USGS, the Department of Ecology and King County collaborated on a study of pesticides in streams in 10 urban watersheds in King County. Water samples were collected from streams during storms and analyzed for 98 pesticides (or their breakdown products). The USGS (1999) reported that 23 pesticides were detected and concentrations of five pesticides exceeded limits set to protect aquatic life. Another part of the study evaluated retail sales of pesticides in King and south Snohomish counties. Many of the most frequently purchased pesticide ingredients, including 2,4-D, MCPP and Diazinon, were detected in all stream samples. This suggests a link between residential use of pesticides and water quality degradation. Many of the routinely detected pesticides (e.g., pentachlorophenol, atrazine, simazine) were not reported in the retail sales data, which suggests that these pesticides are being applied to non-residential areas in the urban watersheds (USGS, 1999).

Metals in Commencement Bay. Metals concentrations in Commencement Bay appear to have declined by almost one-half over the past 15 years, but patterns of contamination are still apparent (Johnson and Summers, 1999). Although Ecology scientists do not routinely evaluate toxic contaminants in marine waters, they conducted a special study of metals in Commencement Bay in 1997 and 1998. Ten stations were sampled, including one in the center of Commencement Bay and three each in the Thea Foss, Blair and Hylebos waterways. All measured metals concentrations were lower than water quality criteria for the protection of marine life. Based on study results, Ecology staff (Johnson and Summers, 1999) concluded that:

- Bay-wide levels of arsenic had declined by almost one-half from levels measured in the early to mid-1980s.
- Zinc, copper and mercury concentrations in Commencement Bay and its waterways were approximately five times as high as levels seen in deep inflowing seawater. Lead, arsenic and nickel concentrations were also elevated but to a lesser degree (approximately twice the values seen in seawater).
- Patterns of contamination within Commencement Bay were apparent: arsenic was relatively high in the Hylebos Waterway and lead was relatively high in the Thea Foss Waterway.

Ecological Risks from Tributyltin in the Surface Waters of Puget Sound. Tributyltin concentrations appear to be declining in Puget Sound and other marine waters of the United States (Cardwell et al., 1999). Scientists from Parametrix, a Kirkland-based consulting firm, recently published an assessment of the ecological risks presented by tributyltin in the nation's coastal waters, including Puget Sound. Using data from U.S. Environmental Protection Agency and Navy monitoring programs, the authors demonstrated that, for saltwater environments, tributyltin concentrations are

Sediment monitoring by NPDES dischargers

Ecology scientists have completed a preliminary review of sediment monitoring data received from entities permitted to discharge wastewater to Puget Sound and other Washington waters (Ecology, unpublished data). Dischargers reporting results to Ecology included aluminum smelters, pulp and paper mills, petroleum refineries, shipyards and municipal wastewater treatment plants.

Some level of sediment contamination was observed at 35 of 50 discharge sites statewide (the majority of the 50 discharge sites are in Puget Sound). Contamination ranged from concentrations of single chemicals slightly above the state's SQS to concentrations of multiple contaminants above the higher CSL. Phthalates were commonly observed in the vicinity of sewage discharges. Metals contamination was commonly observed at shipyards.

The observed levels of sediment contaminants in the vicinity of discharges do not necessarily indicate that a discharge is currently causing sediment contamination. In some cases contamination may have resulted from a facility's historic discharge or from another source.

Commonly used pesticides

2,4-D—an herbicide sold in products such as Weedone and Weed-b-gone.

MCPP—an herbicide also known as Mecoprop and a variety of other trade names.

Diazinon— an insecticide.

Pentachlorophenol— a fungicide sometimes known as penta.

Atrazine—an herbicide also known as Atrex and a variety of other trade names.

Simazine—an herbicide also known as Princep and a variety of other trade names.

significantly higher at marinas than in other environments, including commercial harbors, shipyards and fish and shellfish habitats. The Parametrix analysis showed that tributyltin concentrations in various Puget Sound settings were in the range of concentrations seen elsewhere around the country. For instance, tributyltin in Puget Sound waters was found to pose considerably less risk to aquatic life than contamination in Galveston Bay, Texas but more risk than contamination in Narragansett Bay, Rhode Island.

Data from 1992 to 1996 provide evidence of declining concentrations and ecological risks of tributyltin at marinas in Puget Sound and other coastal waters. This decline may be associated with 1988 restrictions on the uses of tributyltin-containing paints that were enacted because of concerns about the effects of this chemical on aquatic organisms (Cardwell et al., 1999).

Toxic Contaminants in Shellfish

King County Monitoring. In 1998, King County scientists monitored toxic contaminants in shellfish (using butter clams) at four stations located from Richmond Beach south to Normandy Park. Metals concentrations were all well below U.S Food and Drug Administration guidance values for arsenic, cadmium, chromium, lead, nickel and mercury in shellfish. Except for benzoic acid, no organic compounds were detected in any of the shellfish samples. Benzoic acid is used as a food preservative and anti-fungal agent, but it is also produced by metabolic processes and is always detected in shellfish samples. Monitoring results also showed that a concentration gradient does not exist from north to south—arsenic, cadmium, chromium, mercury and nickel concentrations were similar in samples from all four stations. Silver was also detected in samples from all four stations and was slightly higher at the station located just north of the lighthouse at West Point, near the West Point wastewater treatment plant (Table 6).

NOAA Mussel Watch Results for Puget Sound. NOAA's national Mussel Watch monitoring program includes 14 long-term monitoring stations in Puget Sound (Figure 30). An analysis of Mussel Watch data from 1990 to 1996 (NOAA, 1998) showed that 10 of the 14 Puget Sound stations had concentrations of one or more contaminants that were high relative to concentrations seen elsewhere along the nation's coast (Table 7). High concentrations of PAHs were frequently measured at seven of 14 Puget Sound stations. Concentrations of four other contaminants were frequently high at one or more Puget Sound stations: zinc (four stations), nickel (three stations), and lead and butyl tins (one station each).

Eleven of 14 Mussel Watch stations in Puget Sound have a sufficient data record to support analysis of trends over time (i.e., they were sampled during at least six years) from 1986 to 1996 (Figure 30). Decreasing trends in concentrations of one or more contaminants were observed at six of these 11 stations (NOAA, 1998). No increasing trends were observed for any contaminant at any of the Puget Sound Mussel Watch stations. Contaminants that showed declining concentrations include:

- PCBs, which declined at three Puget Sound stations. The most recent measurements at these stations represent 23 to 87 percent reductions from early Mussel Watch measurements.
- Copper, which declined at three Puget Sound stations. The most recent measurements represent 14 to 47 percent reductions from early measurements.
- DDT and its breakdown products, which declined at two Puget Sound stations. One of these stations showed a 57 percent

	Concentration (mg/kg dry weight)								
	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Silver	Zinc
Richmond Beach	15.7	0.83	2.05	12.9	1.55	0.082	5.67	5.04	89.4
West Point	20.7	0.37	1.93	12.7	0.74	0.081	5.89	7.22	94.2
Alki Point	18.9	0.31	1.61	10.8	0.7	0.042	4.95	5.86	90.3
Normandy Park	17.7	0.37	1.67	8.1	0.63	0.04	4.22	5.82	80.2

Table 6. Metals concentrations in butter clams from King County, 1998.

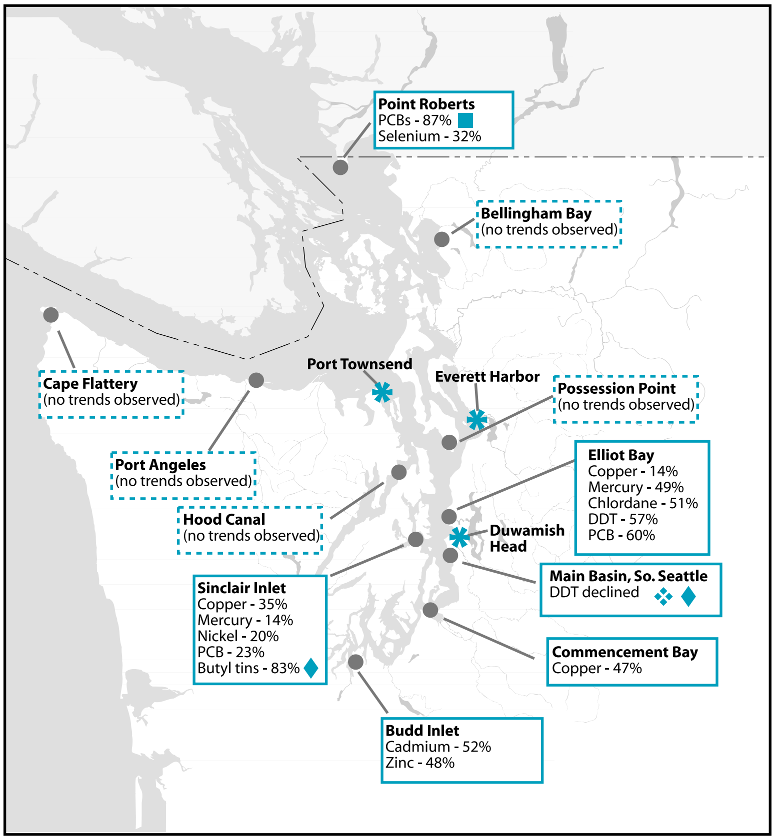


Figure 30. Declining contaminant concentrations in mussel tissue in Puget Sound, 1986-1996.

Values indicate the percent decline observed from 1986 to 1996, unless otherwise noted. No increasing trends were observed at Puget Sound monitoring locations.

Declining trend observed but most recent value is relatively high

Data available for 1989 to 1996 only

Data available for 1986 to 1994 only

Three long-term Puget Sound monitoring stations are not shown because of an insufficient data record to support analysis of trends over time:

- Port Townsend
- Everett Harbor
- Elliott Bay-Duwamish Head

Station (years sampled)	Contaminants present at "high" concentrations in at least one-half of Mussel Watch samples from 1990 to 1996				
	PAHs	Zinc	Nickel	Lead	Butyl tins
Point Roberts (5)			*		
Bellingham Bay (5)	*	*	*		
Everett Harbor (2)	*	*		*	
Possession Sound (5)			*		
Elliott Bay – 4-Mile Rock (5)	*	*			
Elliott Bay – Duwamish Head (2)	*				*
Sinclair Inlet (5)		*			
Main Basin, south Seattle (5)	*				
Commencement Bay (5)	*				
Port Townsend (5)	*				

Source: NOAA, 1998

Table 7. Frequent occurrence of "high" contaminant concentrations in Puget Sound Mussel Watch samples.

"High" concentrations are those greater than the mean plus one standard deviation of the lognormal distribution of concentrations among sites evaluated in the Mussel Watch program in 1989.

reduction in concentrations. The other station showed a declining trend despite a relatively high concentration measured in 1996.

- Mercury, which declined at two stations. The most recent measurements reflected 14 and 49 percent reductions from earlier measurements.
- Six other contaminants, which showed declines at only one station. Reductions from 1986 to 1996 ranged from 20 to 50 percent for nickel, selenium, zinc, cadmium and chlordane to over 80 percent for butyl tins.

Nationwide evidence of decreasing concentrations was seen for chlordane, DDT, PCBs, dieldrin, butyl tins and cadmium (NOAA, 1998). With the exception of dieldrin, decreasing concentrations of each of these contaminants were also evident in Puget Sound. Puget Sound observations of decreasing concentrations of copper and mercury appear to differ from the trends for the entire nation. Increasing trends in concentrations of these and other metals were occasionally observed elsewhere in the Mussel Watch program but never at Puget Sound stations.

Toxic Contaminants in Fish

Scientists at the Washington Department of Fish and Wildlife assess the status and the spatial and temporal trends of contaminant accumulation in Puget Sound fishes and the effects of contamination on fish health. In previous versions of the *Puget Sound Update,* PSAMP monitoring data have shown that:

- English sole and rockfish from urban bays accumulated higher PCB levels than fish in near- and non-urban bays. Exposure to PCB-contaminated sediments was believed to be the main factor associated with PCB accumulation in English sole.
- Pacific salmon from all areas of Puget Sound also accumulated PCBs, with central and south Puget Sound stocks accumulating higher levels than north Puget Sound stocks. Unlike English sole, PCB accumulation in salmon, a pelagic migratory fish, was not directly linked to contaminated sediments but was more likely related to the presence of PCBs throughout the food web.
- Mercury accumulation was detected in all fish species sampled by the PSAMP, but the highest levels accumulated in quillback and brown rockfish, two long-lived species. Rockfish from Sinclair Inlet contained especially high levels of mercury.
- Analysis of data from annual sampling at fixed sites showed no temporal trends in contaminant accumulation. Despite attempts to control sources of variation that can mask trends, data were too variable for most species to demonstrate temporal trends in contaminant accumulation.
- The prevalence of liver disease in English sole was elevated at four urbanized areas in Puget Sound: the Duwamish River, Eagle Harbor, Elliott Bay and Commencement Bay. When compared with the risks for similarly aged English sole from non-urban areas, the likelihood of fish developing liver lesions (tumors) in the Duwamish River was 32 times higher, in Eagle Harbor 11 times higher, and in Elliott Bay and Commencement Bay about six times higher. At most near-urban areas, the likelihood of fish developing liver lesions was two to four times higher than the likelihood of fish from non-urban areas. Although English sole may naturally develop liver lesions as they age, researchers with the National Marine Fisheries Service and Washington Department of

Fish and Wildlife have shown that exposure to contaminated sediments, particularly high molecular weight PAHs, is the main risk factor associated with increased lesion prevalence in English sole.

Since 1997, a substantial portion of the Department of Fish and Wildlife's existing sampling effort has been directed to better defining smaller-scale spatial patterns in contaminant accumulation for English sole and rockfish at selected contaminated areas of Puget Sound. In addition to providing additional geographic coverage for evaluations of English sole and rockfish, Department of Fish and Wildlife scientists have begun monitoring contaminants in Pacific herring because of the fish's importance in the Puget Sound marine food web.

Pilot Study Results for Pacific Herring. In a 1995 pilot study, Department of Fish and Wildlife scientists concluded that Pacific herring were sufficiently exposed to Puget Sound's commonly occurring toxic contaminants (primarily mercury, PCBs and PAHs) to be useful as a monitoring sentinel for these pollutants. Pacific herring are particularly suitable for monitoring temporal trends in contaminant accumulation because they are short-lived, ubiquitous and occupy a low position in the food web. In addition, they comprise a large portion of the diet of many carnivores in the Puget Sound food web, including Pacific salmon, marine birds and marine mammals.

In February 1995, 38 Pacific herring were collected from Fidalgo Bay for chemical analyses (Figure 31). Nineteen whole fish samples were analyzed for mercury, arsenic, copper and lead and another 19 were analyzed for PCBs and chlorinated pesticides. In addition, bile samples from these fish were tested for the presence of PAH metabolites, measured as fluorescing aromatic compounds (FACs).

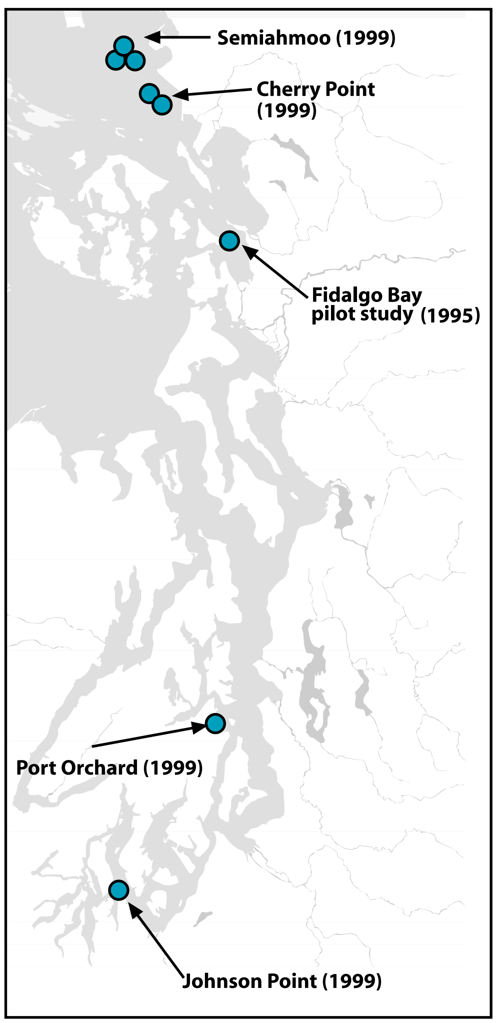


Figure 31. Pacific herring sampling stations.

Results from the Fidalgo Bay pilot study showed that Pacific herring accumulated the same group of contaminants that have been observed in other species from Puget Sound. PCBs were detected in all herring samples, ranging from 38 to 195 µg/kg (micrograms/kilogram), with a mean of 102 µg/kg. Whole body lipid (fat) levels in Fidalgo Bay herring (mean of four percent) were similar to chinook and coho salmon muscle tissue, and were about 10 times greater than muscle from English sole and rockfish. Because PCB concentration can increase with lipid content, the high lipid content of herring may contribute to their PCB levels. The pesticides DDD, DDE and gamma-chlordane were also detected consistently, although at low levels; mean concentrations were 3.4, 17.7 and 4.5 µg/kg,

Table 8. Summary of contaminant results for the PSAMP Pacific herring pilot study, February, 1995.

Parameter (units)	Mean	Minimum	Maximum
Age (years)	3.7	2	5
Whole Body			
Lipids (%)	4.0	0.8	7.8
PCBs (sum of Aroclors µg/kg)	102.3	38.0	195.0
DDD (µg/kg)	3.4	1.2	7.8
DDE (µg/kg)	17.7	3.9	38.4
Total DDTs (µg/kg)	21.1	6.4	44.8
gamma Chlordane (µg/kg)	4.5	0.5	10.6
Mercury (mg/kg)	0.06	0.02	0.10
Arsenic (mg/kg)	1.6	0.9	2.2
Copper (mg/kg)	0.6	0.4	1.0
Lead (mg/kg)	0.0	0.0	0.0
PAH metabolites in bile (FACs ng/g)			
Naphthalene equivalents	227,000	6,850	545,000
Benzo(a)pyrene equivalents	977	53	2,600
Phenanthrene equivalents	65,700	5,200	211,000

respectively (Table 8). Mercury was detected in low levels in all samples; the maximum concentration was 0.10 mg/kg. Arsenic and copper were detected at low levels in all samples and lead was not detected in any sample. PAH metabolites were also detected in Pacific herring. Overall, the concentrations of PCBs, pesticides and metals in whole body samples of Pacific herring from Fidalgo Bay generally fell within the range observed in skin-off fillets of other Puget Sound fish species.

Lead Accumulation in English Sole from Sinclair Inlet. Results of PSAMP monitoring suggest that English sole from the Sinclair Inlet area are exposed to significantly higher lead levels than are sole from any other area of Puget Sound. Between 1989 and 1996 Department of Fish and Wildlife scientists collected 324 composite muscle tissue samples of English sole from 43 different Puget Sound locations. Lead was detected in only 18 of these samples and levels measured were low (0.03 - 0.06 mg/kg). Sixteen of these 18 samples were from Sinclair Inlet and the surrounding bays of Dyes Inlet, Liberty Bay and Port Orchard. Higher lead concentrations were measured in liver tissue than muscle tissue and the same geographic pattern was observed. Lead concentrations in liver tissue of English sole from Sinclair Inlet ranged from 1.8 to 4.7 mg/kg, concentrations significantly higher than those observed at any other location.

Department of Fish and Wildlife scientists evaluated lead accumulation in English sole from six fixed sampling locations throughout Puget Sound and found that of all the urban stations, only lead levels in the fish from Sinclair Inlet were not correlated with their age (Figure 32). At four other fixed sites—two urban stations (Elliott Bay and Commencement Bay) and two non-urban stations (the Strait of Georgia and Hood Canal)—lead concentrations in liver tissue samples were much lower and decreased with fish age (Figure 32). The lowest lead levels were observed at Port Gardner, a near-urban station, where concentrations did not vary with fish age.

The most obvious explanation for the higher concentration of lead in liver and muscle tissue of English sole from Sinclair Inlet is exposure to sediments highly contaminated with lead. Lead levels measured in sediments between 1989 and 1996 at sampling stations near the fish collection locations were also significantly higher at Sinclair Inlet than at the other urban- or near-urban locations. Average sediment lead

New baseline monitoring for Pacific herring

In 1999, the Department of Fish and Wildlife initiated baseline contaminant monitoring of Pacific herring at one Strait of Georgia station and four Puget Sound stations. Results from the 1999 baseline monitoring will show if contaminant levels in herring vary among the north, central and south Puget Sound stations and between Puget Sound and the Strait of Georgia. This information is of interest to PSAMP scientists because the scientists have shown that adult coho salmon from south and central Puget Sound have higher PCB levels than coho from north Puget Sound. Likewise, harbor seals from south Puget Sound have been shown to accumulate higher PCB levels than those from the Strait of Georgia. Future PSAMP efforts will attempt to monitor PCB accumulation in Puget Sound food webs.

levels (dry weight) were 77.2 mg/kg at Sinclair Inlet, 62.6 mg/kg at Elliott Bay, 27.2 mg/kg at Commencement Bay and less than 10 mg/kg at Port Gardner, the Strait of Georgia and Hood Canal. These data were based on one sampling location in each bay. Preliminary results from the 1998 Ecology-NOAA evaluation of contaminated sediments at Sinclair Inlet and Elliott Bay also revealed that most areas in Sinclair Inlet have higher lead levels than Elliott Bay (Figures 33 and 34). The uniformly high lead levels in sediments throughout Sinclair Inlet may expose English sole to higher lead levels than they can effectively metabolize and excrete. Additionally, it is possible that lead is more easily available to English sole from Sinclair Inlet due to the unique mixture of heavy metals present in those sediments.

Liver Disease in English Sole

With their ongoing monitoring of liver condition in English sole from six fixed stations, Department of Fish and Wildlife and National Marine Fisheries Service scientists showed that English sole from three urban locations (Elliott Bay, Commencement Bay and Sinclair Inlet) and one near-urban location (Port Gardner) were significantly more likely (8.7 to 1.8 times) to develop toxicopathic (related to exposure to toxins) liver lesions than English sole from clean reference areas (Figure 35, page 61). The likelihood of English sole from the Strait of Georgia and Hood Canal developing liver disease was statistically indistinguishable from the likelihood of English sole from the other clean reference areas developing liver disease. In addition, the risk of English sole developing liver disease in Elliott Bay increased significantly from 1989 to 1998 (Figure 36, page 61); in 1998, English sole from Elliot Bay were more than twice as likely to develop toxicopathic liver lesions as in 1989. No trends in risk were observed in risk from the other five fixed stations.

Elliott Bay and Sinclair Inlet Focus Studies. Baseline sampling at three urban fixed stations (Elliott Bay, Sinclair Inlet and Commencement Bay) showed that fish from these bays were exposed to and accumulated higher levels of contaminants than fish from near- and non-urban locations. Consequently, the Department of Fish and Wildlife initiated a series of focus studies to better define the extent of contamination in these urban bays. Elliott Bay was sampled in 1997, Sinclair Inlet in 1998, and Commencement Bay in 1999 (Figure 37, page 62).

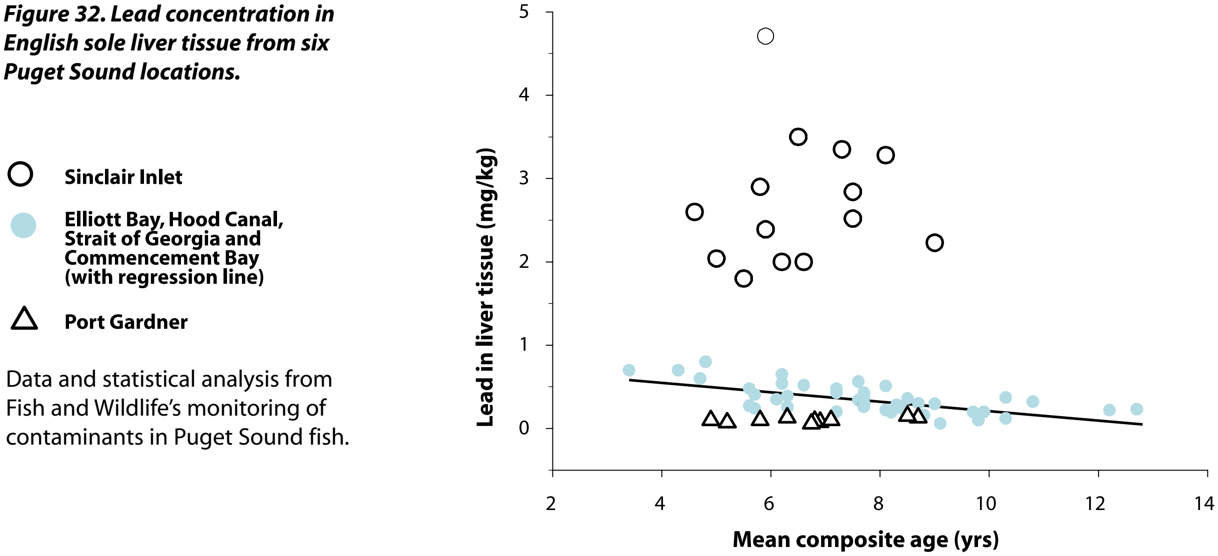
Statistical analysis was used to compute the risk of developing toxicopathic liver lesions for English sole from five Elliott Bay and five Sinclair Inlet locations relative to English sole from clean reference areas. The analysis accounts for the effects of fish age (Figures 38 and 39, page 62). English sole from the Duwamish Waterway (Elliott Bay) were 24 times more likely than those from clean areas to develop lesions; those from the three other inner harbor locations (Harbor Island, Seattle Waterfront and Myrtle Edwards Park) were two to 10 times more likely to develop lesions. The risk to English sole from Alki Point (Elliott Bay) was indistinguishable from the risk to fish from clean reference areas. The risk for English sole from Sinclair Inlet and four surrounding areas was indistinguishable from the risk for English sole from clean reference areas; risks from these five locations were equal to or less than those from clean areas.

Exposure to PAH-contaminated sediments has been shown to be the major risk-factor affecting the development of liver lesions in English sole (Puget Sound Water Quality Acton Team, 1998). Collectively, these data suggest that most of the English sole from Elliott Bay (but not Sinclair Inlet) are exposed to high levels of PAH-contaminated sediments and are developing liver lesions and possibly other health problems as a result (see sidebar). Moreover, the increasing trend in liver lesions in fish from Elliott Bay (Figure 36, page 61) suggests that PAH exposure in these fish is increasing. Inputs of PAHs to Elliott Bay from combined sewer overflows have

Effect of lead on Puget Sound fish

Lead is a non-nutritive, naturally occurring element that is absorbed by the epithelium of a fishes' gills and intestines. It is rapidly metabolized by the liver and accumulates in muscle tissue only when exposures are too high for the fish to effectively metabolize it. At monitoring stations outside of the Sinclair Inlet area, it appears that lead exposures are low enough to be regulated by fish. However, observations of decreasing lead levels in older fish from Elliott Bay, Commencement Bay, the Strait of Georgia and Hood Canal may indicate that older fish are better able to metabolize and excrete lead than younger fish. Alternatively, shifting food habits and habitat may expose older fish to lower lead levels.

Figure 32. Lead concentration in English sole liver tissue from six Puget Sound locations.



Data and statistical analysis from Fish and Wildlife's monitoring of contaminants in Puget Sound fish.

Figure 33. Average lead concentrations in Sinclair Inlet. 1998 Sediment Sampling Strata.

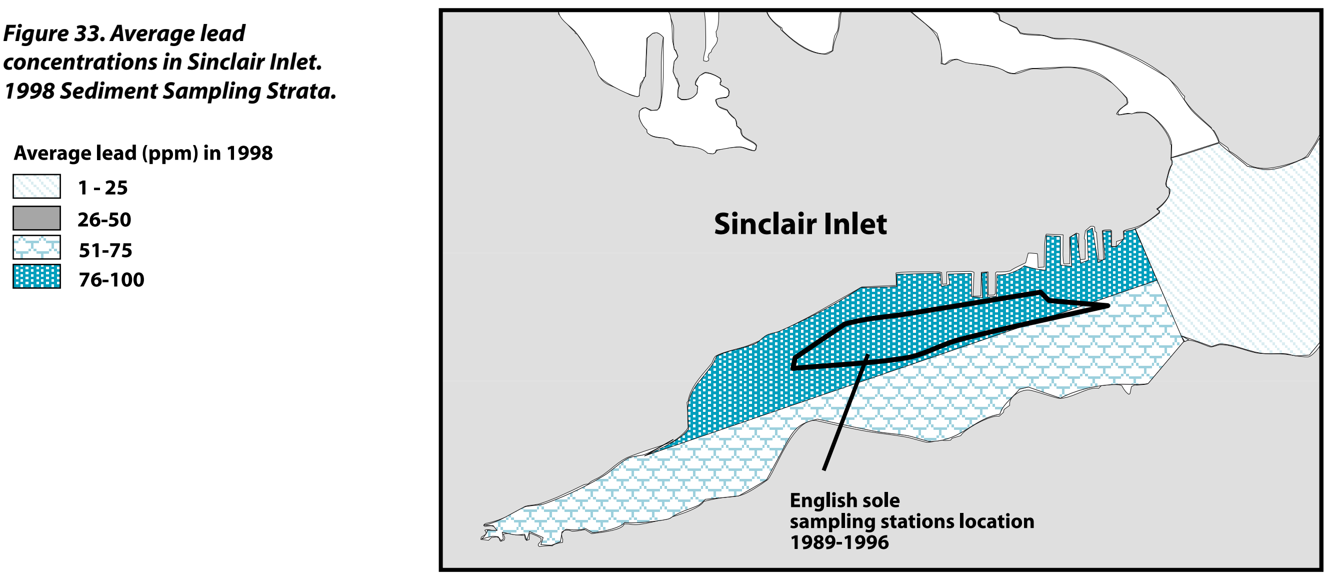
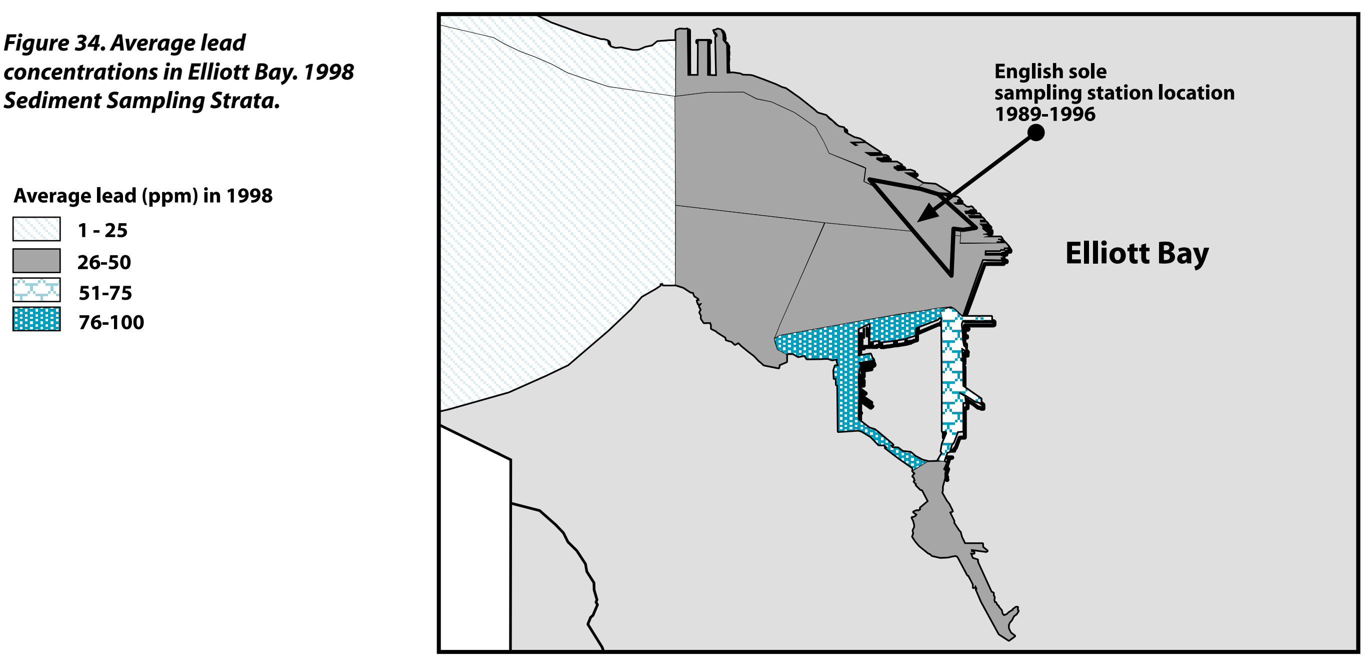


Figure 34. Average lead concentrations in Elliott Bay. 1998 Sediment Sampling Strata.



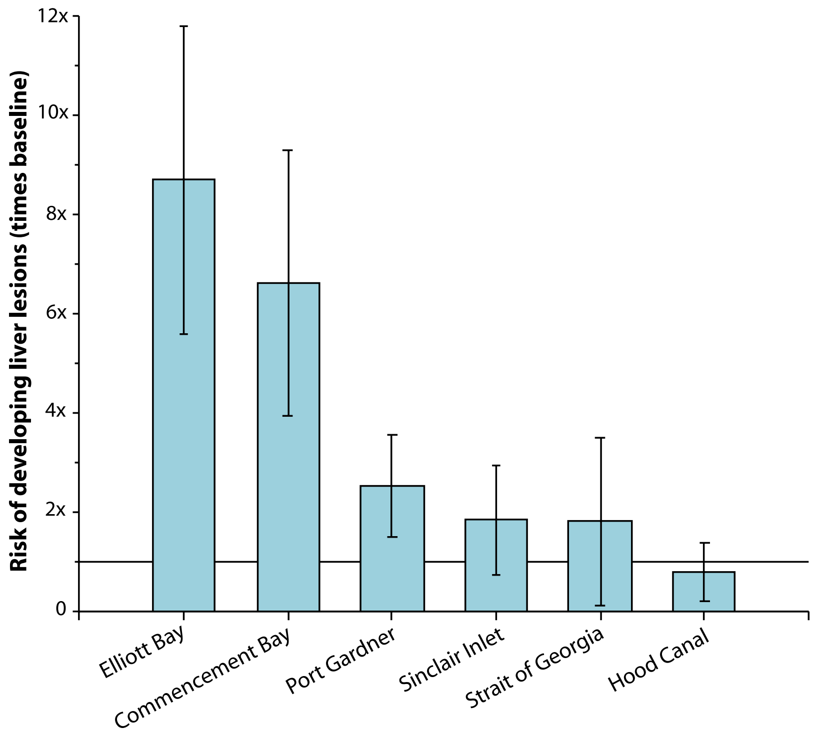


Figure 35. Risk of English sole developing liver disease relative to English sole from clean reference areas, 1989-1998.

Shown here are risks by station averaged over 10 years, ±95% confidence interval. The horizontal line indicates the baseline from which increased risk was estimated.

Risk observed in fish from Elliott Bay, Commencement Bay, Port Gardner and Sinclair Inlet was significantly greater than risk to fish from reference areas. The analysis for the two other locations was inconclusive.

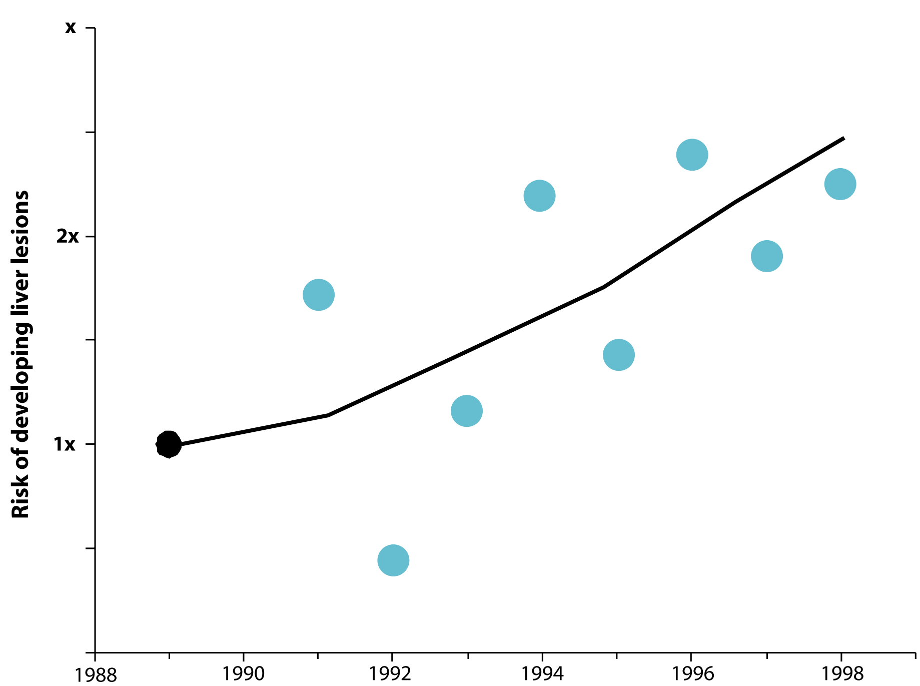


Figure 36. Trend in risk of liver disease in English sole from Elliott Bay.

Logistic regression of odds ratios while controlling for fish age (a covariate), using 1989 as the baseline year ($p=0.005$). No samples were taken in 1990. From 1989 through 1998, the risk of developing liver lesions increased on average by 1.119 each year.

Figure 37. English sole focus study sampling areas.

▲ Sampling station

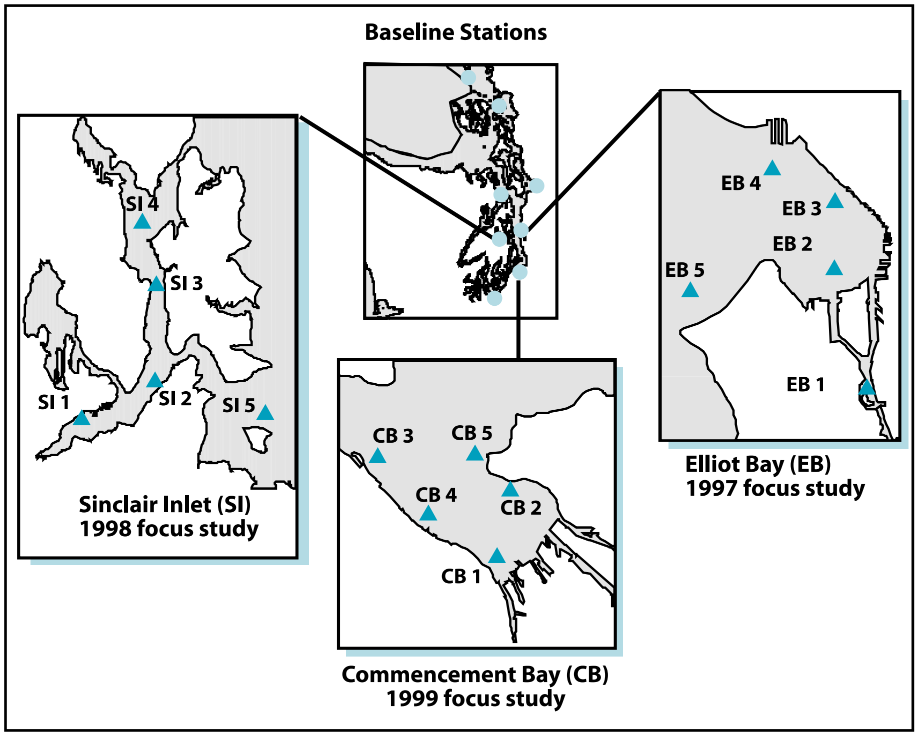


Figure 38. Risk of English sole developing liver lesions in Elliott Bay.

Values:
Greater than 1x indicates elevated risk relative to clean reference areas.

▲ Sampling station

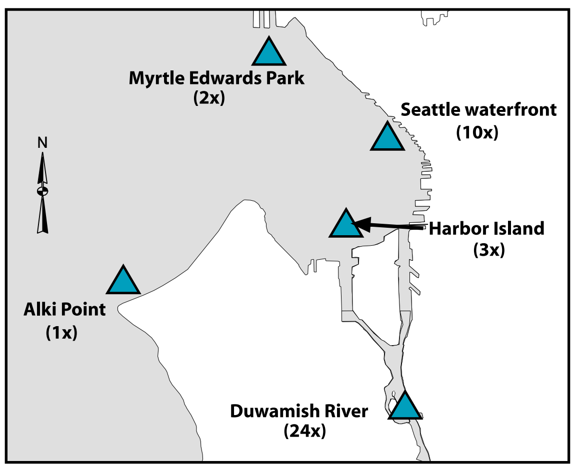
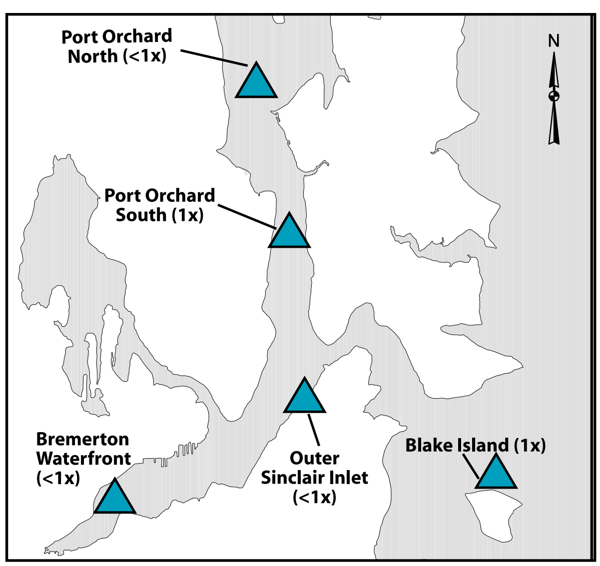


Figure 39. Risk of English sole developing liver lesions from various locations around Sinclair Inlet.

▲ Sampling station



All risks were statistically indistinguishable from clean reference areas (1x or <1x) declined in recent years (King County DNR, 1998) but the status and trends in inputs from stormwater are unknown.

Fish Exposure to PAHs. Exposure to PAHs, especially high molecular weight PAHs, has been associated with increased liver disease and reproductive damage in Puget Sound fishes. Consequently, Department of Fish and Wildlife scientists have started to monitor PAH exposure in Pacific herring, English sole and rockfish by estimating the amount of PAH metabolites in bile, measured as fluorescent aromatic compounds (FACs). PAH metabolites in bile were first measured by the PSAMP for the 1995 Pacific herring pilot study. Since 1997, PAH metabolites in bile samples have been measured in all rockfish and English sole collected for Department of Fish and Wildlife PSAMP monitoring.

Department of Fish and Wildlife scientists performed a preliminary analysis to compare Pacific herring results with recent FAC concentrations measured in English sole and quillback rockfish. Concentrations of FACs were greatest in English sole and rockfish from urban stations, followed by Pacific herring, English sole and rockfish from near-urban stations (Figure 40). The lowest levels of FACs were observed in English sole and rockfish from non-urban stations. More detailed spatial analysis of PAH metabolites in English sole showed that fish from most urban stations were exposed to PAHs levels comparable to those associated with reproductive impairment and liver disease in earlier studies. (Figure 41, page 64).

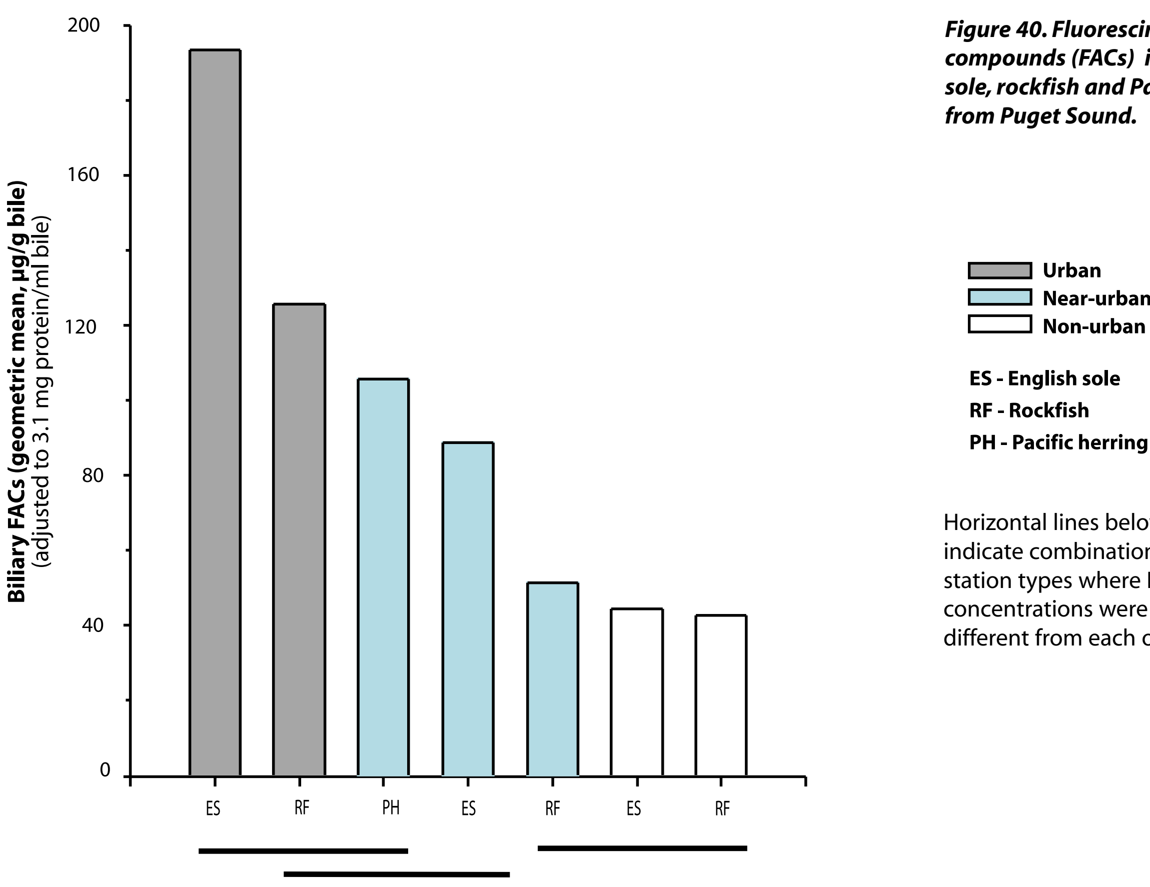
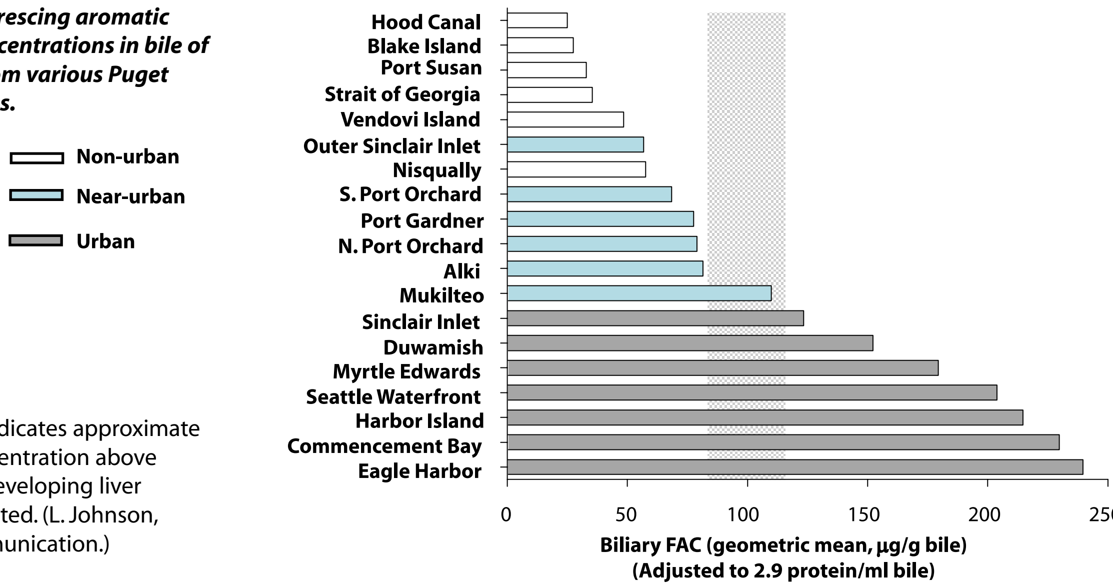


Figure 40. Fluorescing aromatic compounds (FACs) in bile of English sole, rockfish and Pacific herring from Puget Sound.

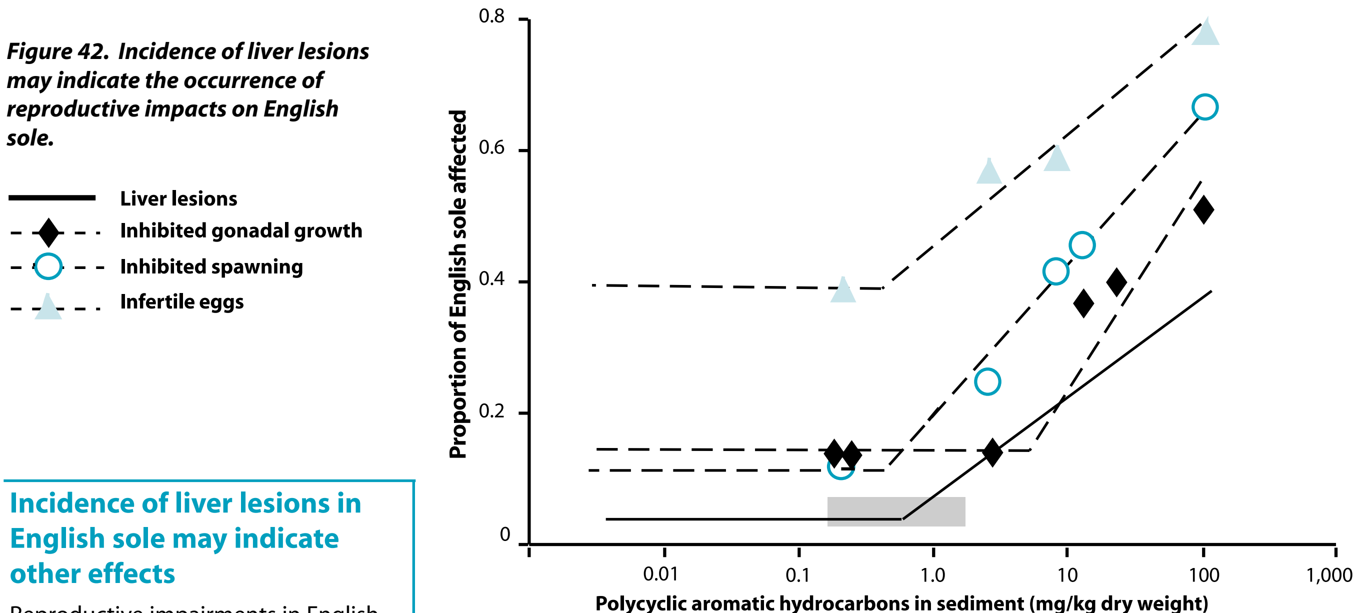
Horizontal lines below the graph indicate combinations of species and station types where FAC concentrations were not significantly different from each other.

Figure 41. Fluorescing aromatic compound concentrations in bile of English sole from various Puget Sound locations.



Shaded area indicates approximate threshold concentration above which risk of developing liver disease is elevated. (L. Johnson, personal communication.)

Figure 42. Incidence of liver lesions may indicate the occurrence of reproductive impacts on English sole.



Source: L. Johnson, personal communication.

Incidence of liver lesions in English sole may indicate other effects

Reproductive impairments in English sole from Puget Sound appear to occur at levels of PAH contamination similar to those associated with increased incidence of liver disease (lesions) (Johnson et al., 1988; Casillas et al., 1991; Johnson et al., 1999; Horness et al., 1998). Studies by National Marine Fisheries Service researchers suggest that the prevalence of reproductive impairments, such as inhibited gonadal growth, inhibited spawning, and infertility of eggs, increases from baseline values at PAH sediment concentrations of about one to five mg/kg. This is approximately the same range at which increases in the incidence of liver lesions have been observed (Figure 42).

Toxic Contaminants in Birds and Mammals

Contaminant Monitoring of Surf Scoters. In 1995, U.S. Fish and Wildlife Service scientists began monitoring contaminants in surf scoters in the Commencement Bay area as part of the PSAMP to determine whether changes in contaminant concentrations in the birds occurred during their wintering period in Puget Sound. Scoters were also collected for contaminant monitoring from Bellingham Bay in 1996 and Hood Canal, near Union, in 1997.

Surf scoters were chosen as a monitoring species because they meet three necessary criteria: 1) they are relatively abundant in Puget Sound, 2) they forage in the marine system, and 3) they spend a substantial portion of their lives in Puget Sound, either as year-round or winter residents. Surf scoters are abundant winter residents of Puget Sound, arriving in September and October and remaining throughout the winter. Scoters begin departing Puget Sound in mid-March to April to return to their northern nesting areas. Surf scoters typically use the low intertidal and subtidal zones.

Location	Average Fall Concentration	Average Winter Concentration
Bellingham Bay	0.91 mg/kg (0.40 to 1.72)	2.82 mg/kg (0.97 to 5.45)
Commencement Bay	2.10 mg/kg (0.82 to 14.09)	2.59 mg/kg (1.24 to 6.87)
Hood Canal	0.85 mg/kg (0.40 to 2.04)	1.85 mg/kg (0.35 to 4.22)

Table 9. Mercury concentrations in scoters at three Puget Sound locations.

Numbers in parentheses indicate ranges of concentrations. The data are reported on a dry-weight basis.

They feed entirely in the marine waters of Puget Sound in the winter. In this study, mussels and clams were their main source of food.

Scientists collected 20 adult male surf scoters from the Commencement Bay area in October when the scoters first arrived in the area and then again in February before they departed. Fifteen adult male scoters were collected from Bellingham Bay and Hood Canal during each sampling period. The purpose of collecting scoters in both the fall and late winter was to document any changes in contaminant concentrations in the scoters during their wintering period in Puget Sound. Liver samples were analyzed for trace metals, organochlorine pesticides and total PCBs. Kidneys were analyzed for selected trace metals. Possible exposure to hydrocarbons was evaluated using bile samples.

Overall, surf scoters collected in this study appeared to be healthy. Concentrations of all the trace metals and organics measured in the scoters' livers and kidneys were well below those known to cause negative impacts to birds. Mercury was the only trace element that increased between the fall and winter sampling periods at all three locations, with the greatest increase occurring in Bellingham Bay (Table 9). Based on this limited sample, it appears that mercury levels have increased during the birds' time in Puget Sound.

Low concentrations of PCBs were recorded in most of the samples from Commencement Bay and in a few samples from Bellingham Bay. PCBs were not detected in the samples from Hood Canal. Low concentrations of DDE were recorded at all three locations. Results of the study indicated that the surf scoters did not have a significant exposure to PAHs during their winter residency at any of the three locations.

Based on results of this study, environmental contaminant exposure does not appear to be negatively affecting surf scoters wintering in Puget Sound. For this reason, collecting surf scoters for contaminant monitoring will not be continued at this time. However, data collected in this study provide baseline information on concentrations of contaminants in surf scoters wintering in Puget Sound. If warranted, contaminant monitoring could be started again in the future. The final report of this study will be available from the U.S. Fish and Wildlife Service in spring 2000.

Scoter abundance on the West Coast appears to be declining (see page 91). Scientists must gain a better understanding of surf scoters' ecology and the environmental stresses they encounter while on nesting grounds, migration routes and wintering grounds in Puget Sound. Additional monitoring of spatial and seasonal patterns of abundance and distribution, and of scoters' use of decreasing resources such as herring stocks or nearshore habitat would provide further knowledge of potential reasons for their decline.

Monitoring Contaminants in Pigeon Guillemot Eggs. Pigeon guillemots are common year-round residents in Washington, nesting along the Strait of Juan de Fuca, Hood Canal, the San Juan Islands and Puget Sound. Pigeon guillemots typically nest in natural cavities in a variety of habitats, including bluffs, rock crevices, driftwood and the undersides of piers. They lay one or two eggs each year.

Studies of estrogen-like compounds in the Puget Sound environment

During the past few years, scientists have become concerned about potential exposure of aquatic organisms to estrogen-like (estrogenic) substances (e.g., natural and synthetic hormones and industrial chemicals) in sewage and industrial effluents. Recent studies indicate that marine flatfish residing in estuaries where large sewage treatment plants are located are exposed to estrogenic compounds (Lye et al., 1998; Mattheison et al., 1998). To determine if exposure to environmental estrogens also occurs in Puget Sound, National Marine Fisheries Service scientists, in collaboration with Washington Department of Fish and Wildlife scientists, are surveying Puget Sound flatfish. Male English sole are being monitored for production of vitellogenin, an estrogen-induced yolk protein that is normally only found in female fish with developing eggs. Their gonadal tissues are also being examined for signs of feminization or other types of abnormal development. Results of the survey should be available later in 2000.

Table 10. Concentrations of PCBs, an organochlorine pesticide and three trace elements in pigeon guillemots at two Puget Sound locations.

Numbers in parentheses indicate ranges in concentration. The data are reported on a wet-weight basis.

Location	Contaminant concentration				
	PCBs	p,p'-DDE	Mercury	Selenium	Arsenic
Protection Island NWR	0.3 mg/kg (0.1 to .7)	0.2 mg/kg (0.04 to 0.20)	0.9 mg/kg (0.5 to 1.3)	0.5 mg/kg (0.3 to 1.2)	0.2 mg/kg (Not detected to 0.6)
Elliott Bay	12.1 mg/kg (11.6 to 13.0)	0.5 mg/kg (0.4 to 0.6)	1.1 mg/kg (0.7 to 1.3)	0.7 mg/kg (0.4 to 1.0)	0.3 mg/kg (0.3 to 0.4)

In 1994, three addled (not hatchable) pigeon guillemot eggs were collected from two nests in conduit holes in a pier in Elliott Bay. In 1996 and 1998, a total of seven addled pigeon guillemot eggs were collected from wooden nest boxes on Protection Island National Wildlife Refuge (NWR). The nest boxes were originally placed on Protection Island NWR to use as part of the PSAMP.

The eggs were analyzed for total PCBs, organochlorine pesticides, mercury, selenium and arsenic (Table 10). To compensate for moisture loss in the addled eggs, a correction factor was used when evaluating the contaminant concentrations.

Total PCBs and p,p'-DDE are the only organochlorine contaminants discussed, as concentrations of the other organochlorine pesticides were either not detected or were present at very low levels. Total PCB concentrations were low in the addled guillemot eggs from Protection Island NWR, while the eggs collected from Elliott Bay had higher levels of total PCBs. The Elliott Bay levels were similar to those in an egg collected in 1982 near Seattle with PCB concentrations of 11.3 mg/kg (Riley et al., 1983). The concentrations of total PCBs in the eggs collected on Protection Island NWR were below levels known to affect hatchability. The concentrations of total PCBs in the eggs collected from Elliott Bay were above levels known to affect hatchability in eggs of some bird species.

Average concentrations of p,p'-DDE in the eggs from Elliott Bay and those from Protection Island were similar and at levels below those known to cause negative impacts to birds. The concentrations of mercury, selenium and arsenic in the guillemot eggs from both locations were also below levels known to negatively affect birds.

Contamination in Harbor Seals. A group of scientists at Cascadia Research Cooperative, Canada's Department of Fisheries and Oceans and the Washington Department of Fish and Wildlife have recently updated analyses of trends in PCB and DDT contamination of harbor seals from south Puget Sound (Calambokidis et al., 1999). Data from earlier studies were evaluated by analyzing archived samples using today's analytical methods. The results of older methods were found to be comparable to results of currently available methods. This finding suggested that data from the earlier studies could be pooled with data from the 1990s to describe changes in contamination in harbor seals from the 1970s through 1997. PCB concentrations in seals declined significantly between the 1970s and 1980s (Figure 43). This decline slowed and became less pronounced in the 1990s. The collaborating scientists hope to collect samples in 2001 or 2002 to extend this analysis of temporal trends.

As discussed in the *1998 Puget Sound Update,* recent work on the contamination of harbor seals also provides detailed information about the specific contaminant compounds (i.e., congeners of PCBs, dioxins and furans) that are present in Puget Sound and Strait of Georgia harbor seals. As reported previously, south Puget Sound seals have a much greater burden of PCBs and related chemicals than do animals from the Strait of Georgia.

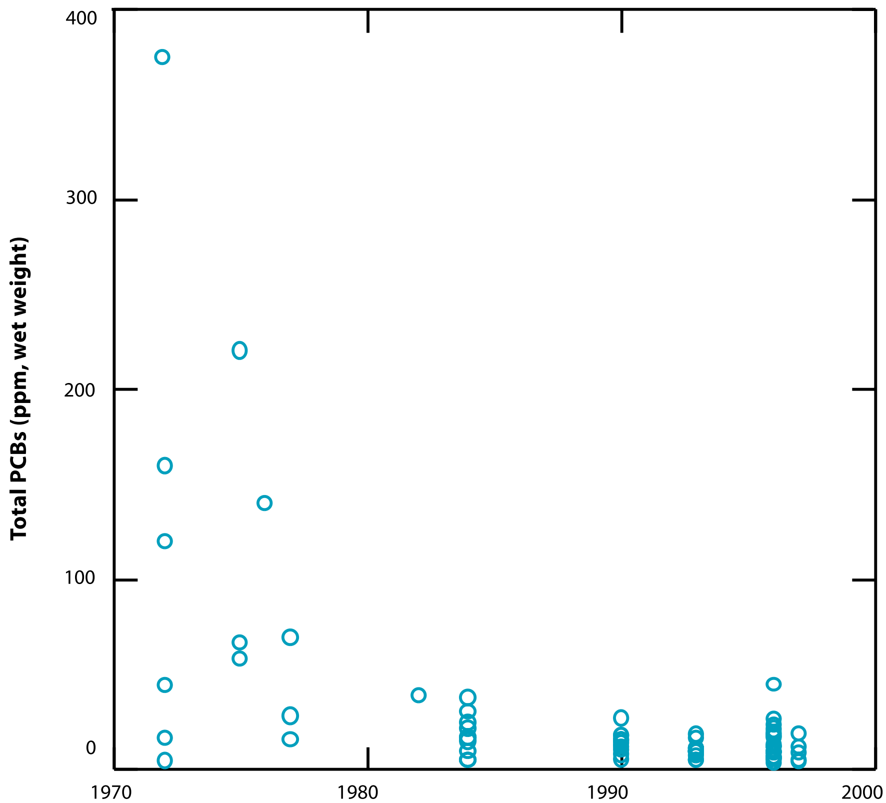


Figure 43. Total PCBs in south Puget Sound harbor seals.

Source: Calambokidis et al., 1999

Acting on the Findings

The information presented in this chapter suggests a number of recommendations for further scientific study or resource management:

- Data from the characterization of sediments in Everett Harbor suggest the need for further investigations of the presence and distribution of dioxins in Puget Sound, especially in areas near potential ongoing and historic sources of these contaminants.
- The Department of Ecology and permitted dischargers should continue to investigate and respond to findings of sediment contamination in the vicinity of discharges. Appropriate actions might include identifying sediments in the vicinity of discharges as part of sediment cleanup sites, evaluating discharges to determine if current discharge levels might cause contamination and continuing to monitor sediment quality in the vicinity of the discharge.
- Environmental managers at the departments of Ecology and Health, the U.S. EPA, the U.S. Navy, the Suquamish tribe and the city of Bremerton should further investigate elevated lead levels in Sinclair Inlet.
- State, local and federal agencies should coordinate to evaluate and respond to the continuing indications from monitoring data that liver lesions in English sole are increasing in Elliott Bay.

- The Department of Fish and Wildlife and the National Marine Fisheries Service should continue investigations of the effects of toxic contaminants and other stressors on fish health. Information on fish abundance should also be collected as an indicator of overall fish health.